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EFFECTS OF GRAVITY ON BODY FUNCTIONS AND PROBLEMS OF SPACE FLIGHT

by P. K. Isakov, Ye. M. Yuganov, and I. I. Kas'yan

Paper presented at the XV International Astronautical Congress, Warsaw, September 7-12, 1964

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Translation of "Gravitatsionnyye vozdeystviya v formirovanii funktsiy organizma i problemy kosmicheskikh poletov"

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The increase in speed and altitude of spacecraft has made it necessary to study a number of new factors, among which weightlessness occupies an important position.

To date a large amount of experimental materials concerning the effects of partial or complete weightlessness on various functions of the body have been published. However, unlike our knowledge about acceleration effects on the body, the mechanisms of the action of weightlessness have still not been generalized into a theory. It is necessary to create a single theory treating the effects on the body of both acceleration and weightlessness as factors of the same category, i.e., equally stemming from changes in the gravitational field.

Under the ordinary environmental conditions encountered by the human organism in the course of a lifetime, the phenomenon of fluctuations in the weight of the organism in a state of rest is practically nonexistent. Both acceleration and weightlessness (partial or complete) occur only as a result of the dynamics of motion. The body is subjected to acceleration and weightlessness during all of its life. Of course, such fluctuations in the weight of the organism as do occur in the course of its movements are insignificant in magnitude and duration. However, their frequency and regularity do have two kinds of effects on the body. On the one hand, fluctuations in weight have a formative effect on the morphological and functional structures of the body; and on the other hand, the body is to a certain extent adaptable when it encounters various physical parameters of weight fluctuation in the course of strenuous activity. Of course, neither the degree of adaptation nor the range of adaptability is the same for acceleration as it is for weightlessness. This is explained by the fact that during the life cycle of the organism the formative effects of acceleration on the morphological and functional structures of the body occur much more often than those of weightlessness. In addition, the action of acceleration may be multiple and exerted in various directions, which naturally is not true with weightlessness.

Under conditions of acceleration and weightlessness, the basic regularities of functions show variations whose appearance and magnitude depend on the force of gravity.

In considering data characterizing the differential threshold of perception of the force of gravity, it must be noted that under these conditions the regularities established by Veber-Fekhner are altered. Thus, in estimating weights by arm movements with the elbow joint immobilized under conditions of acceleration, the sensations of the subject lead him to underestimate the weight of objects. When the weight of an object is estimated using the whole arm, without immobilization, the tendency is to overestimate it. No doubt such fluctuations in estimating the weight of objects are also dependent on the weight of the parts of the arm used in making the estimate. The proportional gain in weight of parts of the arm during exposure to acceleration interferes with the process of estimating the weight of objects. And the greater this gain in weight as more and more of the arm (wrist, forearm, upper arm) is included, the greater the extent to which the weight of the object is overestimated.

Experiments under conditions of short-term weightlessness confirmed the dependence established during exposure to acceleration: the differential threshold of perception of gravitational force decreases during weightlessness (D. V. Afanas'yev, Table 1).

Table I

Range of variations of force (in grams)	On the ground	In horizontal flight	In weightlessness
540 - 650	0.13	0.13	0.09

The table cited shows results obtained with the subject's body and wrist immobilized, the threshold of perception of variations in the force of gravity being determined by the first joint (phalanx) of the index finger. Similar results were obtained when the threshold of perception of variations in gravitational force was determined using the entire forearm without immobilization (Table 2):

Table 2

Range of variations of force (in grams)	On the ground	In horizontal flight	In weightlessness
778 - 945	0.11	0.11	0.09

The accuracy of movements during weightlessness depends, according to the data of many authors, on the degree to which the subject adapts to weightlessness. Thus, in Beck's studies, all subjects improved the accuracy of their execution of assigned movements in proportion to the number of times the experiments were repeated. In the studies of M. A. Cherepakhin, the score for hits in the center of a target accomplished by hand movements reached 86 percent in subjects well-adapted to weightlessness. A similar accuracy was attained by these subjects in horizontal flight. As in Beck's studies, the attempt to control hand movements visually resulted in decreased accuracy.

On comparing these data with those of analogous experiments conducted during exposure to acceleration (V. V. Usachev and others), it may be noted that the results have a general character: change in the weight of the hand (during acceleration or weightlessness) impairs the coordinated functioning of the epidermal and motor analyzers in estimating the weight of objects. The briefer the duration of such changes, the less opportunity the body has to normalize the ordinary interrelations in the activity of epidermal and motor analyzers.

Under conditions of exposure to acceleration and weightlessness, changes in bioelectric activity have a quantitatively contradictory character. It has been established by the experiments of V. I. Babushkin, P. K. Isakov, and others that during increased accelerations up to 5 G's, the amplitude of skeletal muscle biopotentials in man also increases. However, accelerations in excess of 5 G's in the majority of cases are not accompanied by any increase in the amplitude of oscillations. The increase in the amplitude of oscillations is interpreted as the result of increased muscle tone during exposure to acceleration, and is connected with change in the stimulation of proprioceptors.

Studies of the electrical activity of the "antigravity" musculature of animals and human beings have shown that during exposure to weightlessness a sharp drop in the voltage of oscillations occurs, while in a number of cases phenomena similar to a picture of bioelectric silence have been noted (Ye. M. Yuganov, B. F. Asyamolov). On the basis of the data cited, it is possible to state that the degree of tonicity of skeletal musculature during exposure to acceleration and weightlessness is different.

The role and importance of gravitation in the formation of various levels of occurrence of bodily functions may also be somewhat clearly illustrated by the character of changes in several vestibular reaction indices. It has been established that exposure to a constant acceleration that creates a body weight greater than the weight of the human subject under ordinary conditions, as well as the process of increased weight itself, produces pronounced activation of nystagmus reaction indicators. Moreover, the state of weightlessness and the process of lessened weight act as external stimuli leading to the inhibition of vestibular nystagmus. Analysis of numerous data shows that weightlessness results in a level of otolithic stimulation which is quantitatively different from that observed under terrestrial conditions. This is due to the unique character of the functional interaction of the otolithic and cupular structures of the vestibular analyzer and is manifested in an external picture of lowered excitability of the semicircular canals during weightlessness, compared with their excitability under terrestrial conditions or during exposure to acceleration (Ye. M. Yuganov).

Studies of gas metabolism and energy expenditure during the initial phase of adaptation to weightlessness have established that these integral indices of the state of the organism increase their levels. The same studies have emphasized once more the importance of positional adjustment reflexes (body attitudes) in the process of the adaptation of the organism to new amounts of gravity, which also is true during exposure to acceleration. It is extremely important for the realization of space flight to establish the time required for normalization of gas metabolism functions under conditions of weightlessness, bearing in mind the obvious probability that the level of gas metabolism processes in weightlessness will be lower than under terrestrial conditions.

The considerations presented above can naturally only serve as materials on the way to construction of a general theory of the effect of acceleration and weightlessness on the body, and to determination of the role and importance of these factors in the functioning of individual organs and systems. The problem thus defined is considerably broader and deeper than the aspects examined here, and is extremely important practically and theoretically in studies undertaken in preparation for prolonged space flights (including moon flights) in view of the peculiarities of the gravitational field on the moon's surface.

References

1. Babushkin, V. I., Isakov, P. K. Malkin, V. B., and Usachev, V. V. Izucheniye bioelektricheskoy aktivnosti skeletnoy muskulatury u cheloveka pri deystvii radial'nykh uskorenii. (Study of the Bioelectric Activity of the Skeletal Musculature of Man during Exposure to Radial Accelerations). Fiziologicheskiy zhurnal SSSR, Vol. 14, No. 1, 10-13, 1958.
2. Gurfinkel', V. S., Isakov, P. K., Malkin, V. B., Popov, V. I. Koordinatsiya posy i dvizheniy cheloveka v usloviyakh povyshennoy i ponizhennoy gravitatsii. (Coordination of Attitude and Movements in Human Beings Under Conditions of Increased and Decreased Gravitation). Byulleten' eksperimental'noy biologii i meditsiny, No. 11, 12-18, 1959.
3. Isakov, P. K. K teorii gravitatsionnykh vozdeystviy na organizm. (Toward a Theory of the Effects of Gravity on the Organism). Aviatsionnaya i kosmicheskaya meditsina, Materials of the 1963 conference. Moscow, 1963.
4. Marukhanyan, E. V., Isakov, P. V., Asyamolov, B. F., Pavlov, G. I. and Usachev, V. V. Elektrofiziologicheskoye issledovaniye deyatel' nosti kozhnogo i dvigatel'nogo analizatorov v usloviyakh deystviya

uskoreniy. (Electrophysiological Study of the Activity of the Epidermal and Motor Analyzers under Conditions of Exposure to Accelerations). Zhurnal vysshey nervnoy deyatel'nosti, Vol. 12, No. 6, 1021-1028, 1962.

5. Usachev, V. V. Vliyaniye radial'nykh uskoreniy na dvigatel'nyye uslovnyye refleksy. (Effect of Radial Accelerations on Conditioned Motor Reflexes). Zhurnal vysshey nervnoy deyatel'nosti, Vol. 11, No. 1, 22-29, 1961.

6. Yuganov, Ye. M., Isakov, P. K., Kas'yan, I. I., Afanas'yev, D. V. and Pavlov, G. I. Dvigatel'naya aktivnost' intaktnykh zhivotnykh v usloviyakh iskusstvennoy sily tyazhesti. (Motor Activity of Intact Animals under Conditions of Artificial Gravity). Izvestiya Akademii nauk SSSR, seriya biologicheskaya, No. 3, 455-460, 1962.

7. Yuganov, Ye. M., Kas'yan, I. I., Asyamolov, B. F. Bioelektricheskaya aktivnost' skeletnoy muskulatury v usloviyakh peremezhayushchegosya deystviya peregruzok i nevesomosti. (Bioelectric Activity of Skeletal Musculature under Conditions of Alternating Exposure to Acceleration and Weightlessness). Izvestiya Akademiya nauk SSSR, seriya biologicheskaya, No. 5, 746-754, 1963.

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